SPATIAL VIDEO PROCESSING

This invention relates to video processing and particularly to spatial video processing. An important example is the creation of additional lines through spatial interpolation.

A spatial interpolation filter has a filter aperture comprising an appropriate number and arrangement of neighbouring pixels and takes a weighted sum of contributions from pixels within that filter aperture. It has previously been recognised that such a filter can introduce smearing if there are pronounced slopes in the picture material. It is instructive to take the example of a striped image. A filter designed to take weighted sums of contributions along a vertical pixel line will be expected to function correctly as long as the stripes in the image are almost exactly horizontal. Essentially, weighted averages are taken along the stripe and therefore from pixels which are similar. If diagonal stripes are encountered, a weighted sum of contributions along a vertical pixel line will now mix pixels which are from different stripes and which may be very different. Smearing of the image is likely to result.

One approach to this problem, particularly where dealing with interlaced material, is to avoid using spatial interpolation and instead to utilise temporal interpolation. This might work well for stationary pictures but is unlikely to be a satisfactory solution where there is movement between successive pictures.

It has been proposed to improve spatial interpolation by measuring pronounced slopes in the picture material and then rotating the filter aperture into alignment with the measured slope. In the example of diagonal stripes, the angle of the stripe is measured and the filter aperture rotated so that weighted contributions are taken along the stripe, from pixels that remain similar. This proposal can be very helpful if the slope is measured accurately and the filter rotated into precise alignment. This can however be a complex operation. Moreover, if the filter is rotated by the wrong amount, the results can be as bad as, or sometimes worse than, if the aperture remained static. It

is also a factor that if the filter aperture is to be able to accommodate shallow slopes (and it is shallow slopes that produce the most objectionable artefacts), a very wide filter aperture is required.

It is an object of this invention to provide improved video processing in which slopes are accommodated with greater tolerance to errors or variations in slope angles.

It is an object of one form of this invention to meet the performance of prior art slope processing with substantially smaller filter apertures.

Accordingly, the present invention consists in one aspect in video processing apparatus comprising a set of spatial filter apertures and a slope detector, the apparatus selecting the appropriate filter aperture in accordance with the output of the slope detector and taking weighted contributions from pixels in the selected filter aperture, wherein the filter aperture weightings sum to unity over a line including the current pixel and sum to zero over either side of the said line.

Suitably, said line is vertical.

Advantageously, the set consists of three spatial filter apertures.

In another aspect, the present invention consists in video processing apparatus comprising a slope detector and a spatial filter having a positive filter aperture, a linear filter aperture and a negative filter aperture; wherein the positive filter aperture is employed upon detection of any positive slope in excess of a defined positive threshold; the negative filter aperture is employed upon detection of any negative slope in excess of a defined negative threshold; and the linear filter aperture is employed otherwise.

Advantageously, in each said filter aperture weighted contributions are taken from pixels with the filter aperture weightings summing to unity over a line including the current pixel and summing to zero over either side of the said line.

Suitably, said line is vertical.

The invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a diagram showing the pixel weightings for a known linear filter;

Figure 2 is a diagram showing the pixel weightings for a positive slope filter aperture according to an embodiment of the invention;

Figure 3 is a diagram showing the pixel weightings for a negative slope filter aperture according to an embodiment;

Figure 4 is a diagram illustrating the manner of operation of the described embodiment;

Figures 5 to 8 are diagrams illustrating an adaption process according to an embodiment of the invention; and

Figure 9 is a diagram illustrating apparatus according to an embodiment of the invention.

The example will be taken of vertical interpolation. If a four tap vertical filter - such as that shown in Figure 1- is used to vertically interpolate an interlaced picture the resulting image will be soft with various artefacts. One of the most noticeable artefacts is jagging on diagonal lines. Attempts have been made to try and reduce this jagging by twisting the vertical filter so it filters along the direction of the slope of the diagonal line. This will remove the jags, but such a filter is very dependent on knowing the exact slope of line, which is difficult to measure.

A preferred embodiment of the present invention uses a set of three filters. Rather than twisting the simple vertical filter of Figure 1 to interpolate along the direction of the slope, a switch is made to the filter of Figure 2 for a positive slope and to the filter of Figure 3 for a negative slope. (The terms, positive slope and negative slope, in a picture, are often found confusing. In this specification, the nomenclature that is used denotes as positive a slope which rises vertically, from left to right.)

It can be seen that the filters of Figures 2 and 3 use high frequency contributions from horizontally displaced pixels. Thus weightings of the contributions from the central vertical line are the same as in the simple

vertical filter and sum to unity. The weightings on either side of that line, sum to zero. High frequency information from adjacent pixels is thus being used to reduce jags in the image.

A possible explanation for the excellent results achieved with this arrangement is that it allows the removal of jags from edges that are very nearly horizontal (the most objectionable), using a fairly small aperture. Twisting the aperture to interpolate along the edge would require a much larger aperture.

Referring to Figure 4, consider the picture contains a sloping edge, denoted by the solid vertical line. The voltage across the edge varies as shown by the marked parabola. If a vertical [0.5 0.5] filter were used the resulting interpolated voltage would be (b+f)/2, which is considerably larger than the correct result, d. If the aperture were skewed along the diagonal the resulting voltage would be (c+e)/2. In order for this to give the correct result the aperture would have to be 16 pixels wide horizontally. However, using the slope filter according to this embodiment of the invention, the interpolated voltage is (b+f-a+c-g+e)/2, which gives the correct answer.

In one embodiment, the adaption or switch between the positive, linear and negative slope filter apertures is effected as follows. The positive and negative gradients of the input picture signal are first calculated. The difference of these two values is then calculated, giving a gradient difference or switching signal. This signal is then filtered horizontally and vertically to produce a sort of threshold signal. This filtering step also increases the aperture size, considering pixels other than the particular ones specifically analysed in the slope filters, thereby ensuring that the adaption treats a broad range of slopes. If the threshold signal is within a specified range, the usual linear filter is used. However, if it is above this range, the positive slope filter is used, and similarly, if it is below, the negative filter is preferred.

In more detail, the adaption process includes the following steps:-

- Calculate the positive gradient (g_p) using the filter shown in Figure 5

- Calculate the negative gradient (g_m) using the filter shown in Figure 6

- Calculate the difference (d) of the absolute value of these two signals $d = (abs(g_p) - abs(g_m))$

- Filter using 0.25 0.5 0.25 vertically and 0.25 0.5 0.25 horizontally to give f_d

- Threshold signal f_d to form positive slope switching signal for $f_d > 5$, negative slope switching signal for $f_d < -5$ and linear switching signal for $-5 < f_d < 5$

It is advantageous that the gradient filters detect a range of slopes, which is why they are filtered vertically and horizontally by the 0.25 0.5 0.25 filters. Although this increases the aperture size of the mode selection filters (see Figure 7) it produces a worthwhile improvement in picture quality.

The above adaption process is equivalent to dividing the the gradient space into the areas shown in Figure 8. It will be recognised that this is only one example of a thresholding arrangement and modifications will be possible.

Figure 9 illustrates an apparatus according to the above described embodiments. An input signal is passed to a slope detector (900), which on detection of the relevant slope (or lack of), passes the signal to one of the positive slope (902), negative slope (906) or linear (904) filters. Typically, a simple switch between the filter outputs is performed at block 908. In certain cases, the input signal may be passed to more than one of the filters, and the outputs may be mixed in some proportion at 908.

Slope orientation filtering has been shown to give a significant improvement on picture quality over linear filtering. It does not appear to introduce significant artefacts and operates to reduce jagging without

softening the picture. Although the described slope filters appear to work very well, alternatives are possible. In certain applications it may be appropriate to have more than one positive slope filter and more than one negative slope filter, with each filter aperture still having the feature that the pixel weightings sum to unity over the central line of the aperture and sum to zero over all pixels on each side either side of the central line.

Although the example has been taken of vertical interpolation, this invention encompasses other spatial filter operations and orientations other than vertical. In, for example, a horizontal interpolation filter according to this invention, pixel weightings would sum to unity over the central horizontal line of the aperture and sum to zero over all pixels on either side of the central line.

Similarly, although the adaption signal described here behaves reasonably well, numerous alternatives are possible. It will often be useful to include a temporal filter aperture, for use in place of the described spatial apertures, where there is no detected motion.

Some applications may require both de-interlacing and temporal interpolation. If this is the case there are a number of possible methods.

1. De-interlace first, followed by temporal interpolation – the disadvantage with this is the need to store the 1st field.

2. De-interlace both fields at once and then temporally interpolate.

3. Include the temporal interpolation into each of the three adaption filters. In this case you would use the same adaption control for each temporal phase.

It should be understood that this invention has been described by way of examples only and that a wide variety of further modifications are possible without departing from the scope of the invention.